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ABSTRACT

Although the Statistical Package for the Social Sciences (SPSS) contains no subprogram that is complete in itself for analyzing repeated measures or mixed designs analysis of variance, subprogram ANOVA can be used to obtain almost all the required sums of squares for repeated measures designs, mixed designs having repeated measures on some elements, or designs with one or more nested factors. The analysis of either single- or multi-factor designs with repeated (within-subjects) measures on all factors is straightforward, and entails the same number of analyses as the analysis of mixed designs involving both between- and within-subjects factors using SPSS. With more complex designs, such as one in which there are two or more within-subjects factors, the data cards need to be stacked in a special way and two or more SPSS control decks are required. By analyzing the design into its component sums of squares and numbers of degrees of freedom, and then applying subprogram ANOVA successively with appropriate changes in the independent variables and the unit of analysis, the sums of squares for any mixed design may be obtained. (Author/RL)

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REPEATED MEASURES AND MIXED DESIGNS ANOVA USING SPSS

Research designs in education and the social sciences frequently involve repeated measurements of the same observational units (subjects) on one or more variables. The analysis of variance procedures provided by the most popular statistical package--the Statistical Package for the Social Sciences (SPSS), however, are directly applicable only to one-way and factorial designs in which subjects are assigned at random and independently to treatment conditions (Nie, Hull, Jenkins, Steinbrenner & Brent, 1975). Although SPSS contains no subprogram that is complete in itself for analyzing repeated measures data or mixed designs in an analysis of variance format, subprogram ANOVA can be used to obtain almost all the required sums of squares for repeated measures designs, mixed designs having repeated measures on some elements, or designs with one or more nested factors. The remaining sums of squares can easily be obtained as remainders.

Repeated Measures on All Factors

Subprogram RELIABILITY of the SPSS Update (Hull & Nie, 1979) can perform a single-factor repeated measures analysis of variance, but a special procedure must be used when there are two or more factors. The analysis of either single- or multi-factor designs with repeated (within-subjects) measures on all factors is straightforward using subprogram ANOVA. In the single-factor (A) case, for example, two ANOVAs must be run: one with A as the treatment factor and n observations per treatment; a second

with S as the treatment factor and p observations per treatment. If there are p = 4 "A" treatments repeated on n = 5 subjects (S), for example, the SPSS VARIABLE LIST, N OF CASES, INPUT FORMAT, and ANOVA cards will be:

```
VARIABLE LIST   A,S,SCORE
N OF CASES      20
INPUT FORMAT    FIXED(2F1.0,F3.0)
ANOVA           SCORE BY A(1,4)/
                SCORE BY S(1,5)
```

Note that each score, together with its A-S cell designation, is punched on a single card, making a total of 20 data cards. The between A sum of squares (ss_A) and degrees of freedom are found from the first analysis, and the between-subjects sum of squares (ss_S) and degrees of freedom from the second analysis. The residual sum of squares in the second analysis is the within-subjects sum of squares (ss_{wS}), and the error sum of squares (ss_{SA}) is found as a remainder ($ss_{SA} = ss_{wS} - ss_A$).

If the design involves repeated measures on two factors (A and B), one single-factor (S) and three two-factor (AxB, AxS, and BxS) ANOVAs must be run. ss_S and ss_{wS} will be obtained from the single-factor (S) analysis; ss_A, ss_B, and ss_{AB} from the AxB analysis; ss_{SA} from the AxS analysis; ss_{BS} from the BxS analysis. The third error term, $ss_{ABS} = ss_{wS} - ss_A - ss_B - ss_{AB} - ss_{SA} - ss_{BS}$. As an illustration, let p = 4, q = 3, and n = 5. The SPSS control cards are:

```
VARIABLE LIST   A,B,S,SCORE
N OF CASES      60
INPUT MEDIUM    CARD
INPUT FORMAT    FIXED(3F1.0,F3.0)
ANOVA           SCORE BY S(1,5)/
                SCORE BY A(1,4) B(1,3)/
                SCORE BY A(1,4) S(1,5)/
                SCORE BY B(1,3) S(1,5)
STATISTICS      1
READ INPUT DATA
(data cards)
FINISH
```

Mixed Designs

The analysis of mixed designs involving both between- and within-subjects factors using SPSS entails the same number of analyses as complete repeated measures ANOVA.

One Between-Subjects Factor and One Within-Subjects Factor

Consider a fairly simple design with one between-subjects factor (A) and one within-subjects factor (B). Factor A may represent p different methods of instruction, and factor B q different kinds of instructional material. Each student is exposed to only one of the p methods but to all q kinds of material. As outlined by Winer (1971), the required sources of variance, degrees of freedom, and F ratios for this mixed design are listed in Table 1.

Table 1

Summary Table for a Mixed Design ANOVA

Source of Variance	Degrees of Freedom	F Ratio
Between Subjects (S)	np-1	
Method (A)	p-1	ms_A/ms_{SwA}
Subjects within Methods (SwA)	p(n-1)	
Within Subjects	np(q-1)	
Material (B)	q-1	ms_B/ms_{BxSwA}
Method by Material (AB)	(p-1)(q-1)	ms_{AB}/ms_{BxSwA}
Material by Subjects within Methods (BxSwA)	p(n-1)(q-1)	
Total	npq-1	

To perform the analysis in Table 1 using SPSS subprogram ANOVA, the data are first analyzed as an A x B factorial design with n observations per cell and then as an A x S factorial design with q observations per cell. The summary table from the first analysis provides the required sums of squares for A, B, AB and Total. The explained sum of squares in the second analysis is the required between-subjects sum of squares, and the residual sum of squares is the required within-subjects sum of squares. The two error sums of squares (ss_{SwA} and SS_{BxSwA}) are then obtained as remainders. The numerical designation of a given ABS cell and the associated score are punched on a single data card, giving a total of npq data cards. An appropriate set of control cards for a design in which p = 2, q = 4, and n = 3 is:

```
VARIABLE LIST   A,B,S,SCORE
N OF CASES      24
INPUT MEDIUM    CARD
INPUT FORMAT    FIXED(3F1.0,F3.0)
ANOVA           SCORE BY A(1,2) B(1,4)/
                SCORE BY A(1,2) S(1,3)
STATISTICS      1
READ INPUT DATA
   (data cards)
FINISH
```

Two Between-Subjects Factors and One Within-Subjects Factor

Other mixed designs involving repeated measures on certain elements may be analyzed similarly. When there are two between-subjects factors (A and B) and one within-subjects factor (C), the data should first be analyzed as an A x B x C factorial ANOVA with p A conditions, q B conditions, r C conditions, and n observations per cell. The sums of squares for A, B, C, AB, AC, BC, ABC, and Total are obtained from this analysis. Next the data are analyzed as an A x B x S factorial ANOVA with r

observations per cell. The explained sum of squares from this analysis is the required between-subjects sum of squares, and the residual sum of squares is the required within-subjects sum of squares. Finally, the sums of squares for the two error terms (ss_{SwAB} and ss_{CxSwAB}) are obtained as remainders. To illustrate the SPSS control cards for this design, assume that $p = 2$, $q = 2$, $r = 4$, and $n = 3$. The cell designation number (ijk) and the corresponding score for each of the $npqr = 48$ cells are punched on a single card. The control cards are:

```
VARIABLE LIST   A,B,C,S,SCORE
INPUT MEDIUM    CARD
N OF CASES      48
INPUT FORMAT    FIXED(4F1.0,F2.0)
ANOVA           SCORE BY A(1,2) B(1,2) C(1,4)/
                SCORE BY A(1,2) B(1,2) S(1,3)
STATISTICS      1
READ INPUT DATA

(data cards)
FINISH
```

One Between-Subjects Factor and Two Within-Subjects Factors

If there are one between-subjects factor (A) and two within-subjects factors (B and C), as in the previous design the data are first analyzed as an A x B x C factorial ANOVA having n observations in each of the $p \times q \times r$ cells. The sums of squares for A, B, C, AB, AC, BC, ABC, and Total are obtained from this analysis. Then the data are arranged in the form of an A x S design with qr observations in each cell. The residual sum of squares in this analysis is the required within-subjects sum of squares. Next the qr observations in each of the np cells are summed across the r values of C, resulting in an A x S matrix with q observations per cell. From the value of the residual

sum of squares obtained in this A x S factorial ANOVA are subtracted ss_B and ss_{AB}, yielding ss_{BxSwA} as a remainder. Finally the data previously arranged as an A x S design with qr values in each cell are summed across the q values of B, producing an A x S matrix with r observations per cell. From the value of the residual sum of squares obtained in this A x S factorial analysis of variance are subtracted ss_C and ss_{AC}, giving ss_{CxSwA} as a remainder. The values of ss_{SwA} and ss_{BCxSwA} are obtained by subtraction from the sum of squares obtained above.

With more complex designs such as this one in which there are two or more within-subjects factors, the data cards need to be stacked in a special way. COMPUTE cards are used, and two or more SPSS control decks are required. As an illustration, assume that in the above design $p = 2$, $q = 3$, $r = 3$, and $n = 3$. The SPSS control cards for this analysis are:

```
VARIABLE LIST   A,B,C,S,SCORE
N OF CASES      54
INPUT MEDIUM    CARD
INPUT FORMAT    FIXED(4F1.0,F2.0)
ANOVA           SCORE BY A(1,2) B(1,2) C(1,3)/
                SCORE BY A(1,2) S(1,n)
STATISTICS      1
READ INPUT DATA

(data cards) in piles of three cards--value of C=1,2,3)

FINISH
.......

VARIABLE LIST   A,B,S,SCORES1 TO SCORE3
N OF CASES      18
INPUT MEDIUM    CARD
INPUT FORMAT    FIXED(2F1.0,1X,F1.0,F2.0/4X,F2.0/4X,F2.0)
COMPUTE         SCORE=SCORE1+SCORE2+SCORE3
ANOVA           SCORE BY A(1,2) S(1,3)
STATISTICS      1
READ INPUT DATA
(data cards stacked in 18 piles of 3 cards each with successive
```

```
values of C equal to 1, 2, and 3 in each pile)
FINISH
.......

VARIABLE LIST   A,C,S,SCORE1 TO SCORE3
N OF CASES      18
INPUT MEDIUM    CARD
INPUT FORMAT    FIXED(F1.0,1X,2F1.0,F2.0/4X,F2.0/4X,F2.0)
COMPUTE         SCORE=SCORE1+SCORE2+SCORE3
ANOVA           SCORE BY A(1,2) S(1,3)
STATISTICS      1
READ INPUT DATA
(data cards stacked in 18 piles of 3 cards each with successive
values of B equal to 1, 2, and 3 in each pile)
FINISH
```

Other Mixed Designs

Applying computational procedures similar to those described above, the sums of squares for any mixed design may be obtained by successive application of subprogram ANOVA. The user needs only to analyze the design into its component sums of squares and numbers of degrees of freedom and then apply subprogram ANOVA successively with appropriate changes in the independent variables and the unit of analysis. To facilitate this process, the factorial ANOVAs required in using SPSS subprogram ANOVA to analyze designs involving 0-2 between-subjects and 0-2 within-subjects factors are listed in Table 2.

The procedure for mixed designs having proportional but unequal cell frequencies is almost identical to that for designs in which cell frequencies are equal. The only difference is that the maximum cell frequency is specified in the dimensions of the S factor. For example, assume that in the design of Table 1 there are three observations in cells 11, 12, 13, and 14 but four observations in cells 21, 22, 23, and 24. Then the only changes necessitated in the control cards on page 3 are:

```
N OF CASES      28
ANOVA           SCORE BY A(1,2) B(1,4)/
                SCORE BY A(1,2) S(1,4)
```

In the case of a nested design, a separate analysis of variance must be run for each level of the nesting factor. For example, with a three-factor design in which factor B is nested within factor A the first analysis will be an A x C factorial ANOVA. The values of ss_A, ss_C, ss_{AC}, and ss_{TOTAL} are obtained from this analysis. Then a separate B x C ANOVA is run for each level of A. The p different sums of squares for B resulting from these analyses are added to yield the sum of squares for the nested factor. The p different B x C sums of squares are combined to give the B(A) x C sum of squares, and the residual sum of squares from each of the p analyses of variance are combined as the sum of squares within cells. An example of SPSS control cards for a nested design in which factor B is nested within factor A and $p = 2$, $q = 2$, $r = 3$, and $n = 5$ is given below. Note the use of the SELECT IF control cards:

```
VARIABLE LIST   A,B,C,SCORE
N OF CASES      60
INPUT MEDIUM    CARD
INPUT FORMAT    FIXED(3F1.0,F3.0)
ANOVA           SCORE BY A(1,2) C(1,3)
STATISTICS      1
READ INPUT DATA
(data cards)
*SELECT IF      (A EQ 1)
ANOVA           SCORE BY B(1,2) C(1,3)
STATISTICS      1
*SELECT IF      (A EQ 2)
ANOVA           SCORE BY B(1,2) C(1,3)
STATISTICS      1
FINISH
```

Table 2

Factorial ANOVA Designs to Obtain Components for Various Repeated Measures and Mixed Designs*

Number of Within-Subjects Factors	Number of Between-Subjects Factors		
	0	1	2
0		A (n)	AxB (n)
1	A (n) S (p)	AxB (n) AxS (q)	AxBxC (n) AxBxS (r)
2	AxB (n) S (pq) AxS (q) BxS (p)	AxBxC (n) AxS (qr) AxS (B summed over C = q) AxS (C summed over B = r)	AxBxCxD (n) AxBxS (rt) AxBxS (C summed over D = r) AxBxS (D summed over C = t)

*The letters in parentheses refer to the number of observations in each cell of the single-factor or multi-factor design.

References

Hull, C. H., & Nie, N. H. SPSS update. New York: McGraw-Hill, 1979.

Nie, N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K., & Brent, D. H. SPSS: Statistical package for the social sciences. New York: McGraw-Hill, 1975.

Winer, B. J. Statistical principles in experimental design (2nd ed.). New York: McGraw-Hill, 1971.